SHEET MATERIAL INFILTRATION OF POWDER METAL PARTS

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims the benefit of United States Provisional Patent Application No. 60/542,271 filed February 4, 2004.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

[0002] Not Applicable.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0003] This invention relates to manufacturing powder metal parts, and in particular to the infiltration of powder metal parts with a metallic material such as copper.

2. Description of the Related Art

[0004] Powder metal parts are used to produce many automotive components that have a need for net-shaped components. Powder metal components are typically produced by pressing a powder metal in a die into a compact of a desired shape and thereafter sintering the compact to increase the strength of the part.

[0005] It has been reported that conventional powder metal parts, produced by pressing and sintering, have inferior impact and fatigue strength because of the presence of pores in the sintered parts. Accordingly, methods have been proposed to remove porosity and achieve nearly full density in the parts. One method for obtaining nearly full density is to infiltrate the powder metal parts with a metal such as copper. See, for example, U.S. Patent Nos. 6,676,894, 6,551,373, 6,500,384, 5,925,836, 5,574,959, 5,031,878, 4,976,778, 4,861,373, 4,836,848, 4,769,071, 4,734,968, 4,731,118, 4,606,768, 4,485,147, 4,424,953, 4,412,873, 4,168,162, 4,008,051 and 3,829,295.

[0006] Infiltration is the process of filling the interconnected pores of the powder metal compact with a molten metal or alloy (the "infiltrant") of lower melting point by capillary action. For example, copper infiltrated steels are manufactured by compacting iron or iron-base powder (with or without graphite powder) into a finished shape and infiltrating the interconnected pores with a copper base material during the sintering operation. This may be a single pass or

two stage infiltration. The result is a steel-copper structure unique to the powder metallurgy process. Compared with as-sintered iron or carbon steel powder metal parts, copper infiltration can improve tensile strength, fatigue strength, elongation, hardness, and impact properties.

[0007] In the past, the source of copper for infiltrating a powder metal part was a powder metal copper compact, i.e., a part made from copper powder that is pressed together to maintain its shape. However, using a copper powder metal compact as the source of infiltrating copper has drawbacks. For example, (1) residue may remaining after infiltration; (2) erosion of the base metal surface at the point of infiltrant entry may occur; (3) infiltration localization may be difficult because certain shapes may not be practical via conventional powder metal infiltrant compacts; (4) breakage associated with fragile powder metal infiltrant compacts may occur; and (5) positioning of the powder copper compacts may be difficult.

[0008] Therefore, there is a need for an improved process for infiltrating porous powder metal parts with a metallic material such as copper.

Summary Of The Invention

[0009] The present invention meets the foregoing needs by providing an alternative to using a powder metal compact as the infiltration source. An infiltration process according to the invention uses a stamped metallic sheet material as a source of metal for infiltration to achieve a high strength powder metal article. In one form, an infiltration process according to the invention uses a stamped wrought copper sheet material as a source of copper for infiltration to achieve a high strength powder metal iron or steel article.

[0010] In one aspect, the invention provides a process for manufacturing a metal-infiltrated powder metal part. In the process, a powder metal is compacted to form a compact, and an infiltrant blank is formed from a wrought metal sheet. The infiltrant blank is placed in contact with the compact, and the compact is sintered at a temperature sufficient to form a sintered compact with a matrix having pores and to melt the wrought metal such that the melted wrought metal infiltrates the pores of the matrix to form a metal-infiltrated powder metal part. Location of the blank on top of the compact improves infiltration of the wrought

metal. In one embodiment, the powder metal is selected from iron and iron alloys, and the wrought metal is selected from copper and copper alloys. It can be beneficial for the wrought metal sheet to have a thickness of less than 1 millimeter. The infiltrant blank may formed by a method such as stamping, fine blanking or abrasive water jet cutting.

[0011] In another aspect of the invention, the infiltrant blank may be formed with a locating element that is suitable for engaging a corresponding locating element on the compact, and the infiltrant blank may be placed in contact with the compact such that the locating element of the blank engages the corresponding locating element on the compact. For example, the locating element of the blank may be a section of the blank extending outwardly from a body of the blank. As a result, positioning of the blank is improved on the compact.

[0012] In yet another aspect of the invention, the compact is separately sintered at a temperature sufficient to form a sintered compact with a matrix having pores, and an infiltrant blank is formed from a wrought metal sheet. The infiltrant blank is then placed in contact with the sintered compact, and the wrought metal is melted such that the melted wrought metal infiltrates the pores of the matrix to form a metal-infiltrated powder metal part.

[0013] Some advantages of utilizing wrought metallic sheet instead of a powder metal compact for the infiltration material are: (1) a reduction in the amount of residue remaining after infiltration; (2) a reduction in the amount of erosion of the base metal compact surface at the point of infiltrant entry; (3) improved selective infiltration localization because the sheet stamping process facilitates shapes with geometry not practical via conventional powder metal infiltrant compacts such as thin webs, and missing areas; (4) improved infiltration process quality due to the elimination of the breakage associated with fragile powder metal infiltrant compacts; and (5) improved positioning of the stamped sheet blanks due to the stamping processes' ability to form locating features to interlock or engage with the component to be infiltrated.

[0014] These and other features, aspects, and advantages of the present invention will become better understood upon consideration of the following detailed description, drawings, and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Figure 1 shows a top view of a copper infiltrant blank resting on an iron base compact before sintering in accordance with one version of the invention.

[0016] Figure 2 shows the details of experimental test pieces after sintering and infiltrating.

DETAILED DESCRIPTION OF THE INVENTION

[0017] In an example process for manufacturing a metal infiltrated powder metal part according to the present invention, an iron or iron alloy powder is introduced into a die having the desired shape of the final part. The powder metal is then compressed in the die to a higher density article commonly known as a "green compact". Typically, iron-based green compacts have a density of 6.0 g/cc to 7.3 g/cc. (Theoretical density for iron is 7.88 g/cc.) Next, the desired amount of copper or copper alloy wrought sheet is formed into the desired shape for the infiltrant blank, and the blank is placed in contact with the green compact such that the copper may infiltrate the pores of the compact upon heating.

[0018] The compact and the copper blank placed in contact with the compact are subjected to a conventional sintering process performed at a predetermined temperature above the melting point of copper (e.g., 1100°C) for a fixed amount of time (e.g., 15 minutes) in a suitable atmosphere (e.g., a reducing atmosphere having hydrogen). Typically, the sintering process promotes the bonding or diffusion between the iron or iron alloy powder particles to create a sintered compact with a matrix having pores. During the sintering process, the melted copper flows into the pores in the matrix. The melted copper wicks, via surface tension, gravity and capillary action, into the open porosity of the matrix. Therefore, molten copper fills the pores of the matrix, thereby increasing the density and integrity of the matrix. The amount of copper infiltrated depends on the physical and mechanical properties that are desired in the matrix. When only a partial infiltration into the matrix is desired, the amount of copper is reduced. Porosity measurements of the green compact can be used to determine the amount of copper infiltrant needed.

[0019] In an alternative process, the compact alone is first subjected to a conventional sintering process to form a sintered compact with a matrix. In a

second step, the copper infiltrant blank formed from the wrought sheet is placed in contact with the sintered compact and the copper sheet and the sintered compact are heated at a predetermined temperature. During the second step, the copper melts and flows into the pores in the previously sintered porous matrix. The copper melts and wicks, via surface tension, gravity and capillary action, into the open porosity of the matrix.

[0020] Figure 1 shows an example combination of a compact and an infiltrant blank suitable for use in a process of the invention. A copper infiltrant blank 10 about 0.032" (0.8128 mm.) thick in the form of a ring is shown resting on the top 22 of a tubular iron base compact 20 before sintering. The top 22 of the compact 20 has recessed areas 24a, 24b, 24c and 24d that receive tabs 14a, 14b, 14c and 14d that extend outward from the perimeter edge 12 of the body of the blank 10.

[0021] The tabs 14a, 14b, 14c and 14d provide locating features to interlock with or engage the recessed areas 24a, 24b, 24c and 24d in the compact 20 to be infiltrated with the copper of the blank 10. In the embodiment shown, the tabs 14a, 14b, 14c and 14d extend outward from the blank 10 and engage recessed areas 24a, 24b, 24c and 24d in the compact 20. However, in an alternative configuration, the blank may include recesses that engage outwardly extending locating features of the compact.

[0022] The copper infiltrant blank 10 may be formed by stamping, fine blanking or abrasive water jet cutting wrought copper or copper alloy sheet material. By "wrought", we mean a material shaped by a mechanical action such as rolling, forging, extrusion or drawing. A wrought material typically has a density greater than 99% theoretical density. Thus, compacted powder materials are not considered to be wrought materials as compacted powered materials typically have a density of 93% or less of the theoretical density. Exemplary wrought copper materials have thicknesses of 0.001 to 0.250 inches (0.0254 to 6.35 mm.). Wrought copper materials having thicknesses of less than 0.039 inches (1 mm.) are particularly advantageous. Suitable copper alloys include brass and bronze.

Examples

[0023] The following Examples have been presented in order to further illustrate the invention and are not intended to limit the invention in any way.

1. Experimental Methods

[0024] Three infiltration techniques were compared versus a non-infiltrated control test. Standard test rings measuring nominally 2.0" (50.8 mm.) outside diameter x 0.75" (19.05 mm.) inside diameter x 1.125" (28.575 mm.) long were used, made of a material meeting specification Std 35 FC-0208 of the Metal Powder Industries Federation (MPIF). MPIF Std 35 FC-0208 is as follows: Elemental Iron powder 93.2-97.9 weight percent; Elemental Copper powder 1.5-3.9 weight percent; Carbon (as graphite powder) 0.6-0.9 weight percent; and Other Elements 2.0 weight percent maximum.

[0025] The base compacts were pressed to a density of 6.95 g/cc. Eighteen test rings were manufactured for the infiltration.

[0026] The three infiltration techniques explored were: (1) a not-infiltrated (control) based on MPIF Std 35 FC-0208; (2) a standard powder metal copper infiltration as described in MPIF Std 35 (FX series), i.e., using a powdered copper infiltrant material and pressing it to form a compact of a shape suitable to lay on the top of a compacted iron or iron-base powder metal article for subsequent copper infiltration during sintering; (3) a dual feed process where copper powder was mixed with MPIF STD 35 FC-0208 material, the die was then lowered and a second fill with copper infiltration material was added and compacted; and (4) infiltration using a 0.032" (0.8128 mm.) thick copper stamping material cut using tin snips to produce a shaped copper source the same area as the test ring.

[0027] All test pieces were sintered in a 24" muffle furnace at normal sintering conditions, that is, at 2050°F (1121°C) for 15 minutes in a 90% nitrogen -10% hydrogen atmosphere.

[0028] Figure 2 shows the details of the test pieces after sintering/infiltrating. The top row is of the Dual Feed process. The second row from the top is the standard ring with pressed powder copper compact rings set atop. The second row from the bottom is the standard ring with a pre-fabricated copper stamping set atop. The bottom row is the standard ring. Notice the amount of skull left on the top two rows. The pre-fabricated stamping leaves no skull.

2. Test Results

[0029] Density measurements were taken and are shown in Table 1.

Table 1

Processes	Density (g/cc)
(1) Control base process non infiltrated	6.88
(2) Conventional Copper Infiltration Using Copper Powder Compacts	7.57
(3) Dual Feed Material	7.57
(4) Infiltration by Copper Stamping	7.62

[0030] The infiltration by copper stamping according to the invention produced the highest density and is therefore a suitable replacement for powder metal infiltration. It may also be possible to use a wrought sheet material other than copper as the source of the infiltration material.

[0031] Erosion/Cleanliness readings were taken and are shown in Table 2.

Table 2

Process	Comments
(1) Control base process non infiltrated	As sintered
(2) Conventional Copper Infiltration Using Copper Powder Compacts	Normal residue and erosion for this process
(3) Dual Feed material	Dual Feed creates the effect of more erosion compared to conventional copper infiltration (2)
(4) Infiltration by Copper stamping	Reduced erosion and minimal residue compared with conventional copper infiltration (2)

3. Conclusions

[0032] Dual feeding of material was not a suitable method for infiltration of powder metal articles.

[0033] Conventional copper infiltration produces significant residue and erosion. It is difficult to align the pressed copper infiltrant slug causing inconsistent infiltration. Due to the fragile green strength of the pressed infiltrant

material, the infiltration process is subject to high scrap when the infiltrant slug is thin due to handling breakage.

[0034] Infiltration by copper stamping is a unique process and has the following advantages: (1) the process is a low erosion infiltration process; (2) the process is a low residue infiltration process; (3) the process is a selective infiltration process by stamping shapes with geometry not practical via conventional powder metal infiltrant slugs such as thin webs and missing areas; (4) the process uses thin gauge copper materials and therefore eliminates the breakage associated with powder metal infiltrant slugs, thereby reducing scrap and improving quality; and (5) the process allows for the use of stamping location features such as “ears”, “lips” or “tabs” or other readily stamped orientation features.

[0035] Thus, the invention provides an alternative to using a powder metal compact as the infiltration source. An infiltration process according to the invention uses a stamped metallic (e.g., copper) sheet material as a source of metal (e.g., copper) for infiltration to achieve a high strength powder metal (e.g., iron or steel) part.

[0036] Although the present invention has been described in considerable detail with reference to certain embodiments, one skilled in the art will appreciate that the present invention can be practiced by other than the described embodiments, which have been presented for purposes of illustration and not of limitation. Therefore, the scope of the appended claims should not be limited to the description of the embodiments contained herein.

INDUSTRIAL APPLICABILITY

[0037] The invention relates to a process for producing stronger, higher density and improved surface texture powder metal parts.